LATTE – Linking Acoustic Tests and Tagging Using Statistical Estimation: Modeling the Behavior of Beaked Whales in Response to Mid-Frequency Active Sonar

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LONG-TERM GOALS

The goal of this project is to improve our ability to predict the behavioral response of beaked whales to mid-frequency active (MFA) sonar, by making better use of data already collected, or being collected as part of other projects.

OBJECTIVES

We aim to construct and fit mathematical models of the diving behavior of beaked whales, and their response to MFA sonar. These models will be parameterized by fitting them simultaneously to three sources of data: (1) short-term, high fidelity tagging studies on individual whales (some of which comes from animals exposed to acoustic stimuli); (2) medium-term satellite tagging studies of individual whales (some of which we hope will come from data collected during navy exercises); and (3) long-term passive acoustic monitoring from bottom-mounted hydrophones (much of which comes

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from data collected during navy exercises). All data will come from the Atlantic Undersea Test and Evaluation Center (AUTEC), Bahamas, and the surrounding area. Hence our models and predictions will be directly applicable to animals in that area, although we hope they will be of more general relevance.

Outputs of the model are designed to be compatible with risk evaluation and mitigation tools and models developed under other ONR initiatives, such as Effects of Sound on the Marine Environment (ESME) and Population Consequences of Acoustic Disturbance (PCADS). Hence, the model will:

(1) predict the behavioral responses of individual beaked whales to MFA sonar;

(2) provide sufficient information to assess the level of "take" that is likely as a result of sonar operations;

(3) provide sufficient information to allow the energetic costs of disturbance by MFA to be estimated; (4) provide a modeling framework within which information concerning behavioral responses of beaked whales can be interpreted.

APPROACH

The overall modeling framework we are adopting is called a "state-space model". Such models describe the evolution of two stochastic time series in discrete time: (1) a set of true but unknown, states, which in our case are the positions of diving whales, and (2) a set of noisy observations related to these states, which in our case are the three sources of data described above. A "process model" describes how the states change through time, and a set of "observation models" describe how the observations link to the states. Here, the process model is a stochastic, discrete-time model for the movement of individual diving beaked whales, and their group dynamics.

The work of the project is divided into four tasks, each divided into subtasks, as described in the project proposal.

- Task 1 involves specifying the process model; this is largely the responsibility of the main postdoctoral research fellow working on this project, Dr Tiago Marques, in collaboration with Thomas, Boyd and Harwood.
- Task 2 involves developing the formal fitting procedures required to fit the state-space model to the three sources of data. Computer-intensive Bayesian statistical methods will be used. Such methods have been the subject of enormous growth in research activity recently; nevertheless fitting complex movement models to data at such a range of temporal scales is very challenging, and considerable effort is being devoted to algorithm development. This is being undertaken by Marques and Thomas.
- Task 3 involves processing the data required for input to the model. A large amount of acoustic and tag data are potentially available, but much of it requires extraction and processing to bring it into a form that's useful for this project. This is being undertaken by staff at NUWC, under the direction of Moretti.
- Task 4 involves project supervision and coordination. This includes monthly tele-conference progress meetings, as well as face-to-face meetings at least once a year, and is coordinated by project manager Catriona Harris at St Andrews.

WORK COMPLETED

The project started in April 2010. We have been able to take advantage of travel opportunities largely funded under other projects to meet face-to-face in April in St Andrews, in Newport, RI in July and again in September. This has greatly facilitated project start-up. Moving forward, we will begin to rely more heavily on tele-meetings, as planned.

The first sub-task under task 1 was to review current models for marine mammal diving behavior. This is now almost complete, and is being written up as a working paper. We have also begun the second task: mathematical development of the model we intend to use.

For task 2, the first subtask was an exploratory data analysis. We have been doing initial analysis of data from Submarine Commander Course (SCC) exercises that were held at AUTEC in May 2007 and 2008, as well as simple initial analysis of digital tag (DTag) data collected during August and September 2007. The next subtask is to perform initial fitting of simplified models to these data; we are exploring the potential for use of the Kalman filter for this.

Under the third task, SCC and DTag data have been processed and provided; further data processing will take place as required.

As mentioned above, project coordination (task 4) has been greatly facilitated by opportunities for face-to-face meetings. We have also been able to coordinate with other projects, mentioned under "Related projects", below.

RESULTS

No concrete results as yet.

IMPACT/APPLICATIONS

Determining and mitigating the effect of mid-frequency active sonar on marine mammals is a key goal for the US Navy in complying with marine mammal protection requirements. The proposed research is aimed at developing tools to facilitate this. Although current behavioral response experiments provide key information, it seems unlikely that they will ever yield large enough samples to provide a complete picture of the response of vulnerable species to sonar. By combining information from these rare, directed studies with the large amount of opportunistic data available from exercises on instrumented testing ranges, obtaining the required information about animal response becomes feasible. This information could possibly be used to avoid future mass strandings, and can certainly be used to better estimate the number of animals exposed to high levels of sound (likely fewer than currently assumed).

RELATED PROJECTS

- Behavioral Response Study – an experimental approach to determining the behavioral response of marine mammal species to MFA sonar that provided the motivation for, and much of the data for, the current study.

- M3R program – the passive acoustics monitoring algorithms and tools development program at NUWC that has facilitated much of the data processing work used in the current project.
- DECAF – a project developing methods for density estimation from fixed acoustic sensors that provided the initial monitoring tools being further developed in this project.
- PCAD – a project to implement the population consequences of acoustic disturbance model to four case study species including beaked whales at AUTEC. Output from the LATTE project will provide useful input into PCAD-type models, even if the outputs come too late for direct use in the current PCAD project.
- The way they move – a research project at the University of St Andrews developing algorithms for fitting state-space models to terrestrial animal tag data; the current project is leveraging many of the findings from this project.